

To be presented at the 36th AIAA/ASME/SAE/ASEE
Joint Propulsion Conference and Exhibit
16-19 July 2000, Huntsville, Alabama

Technical Paper AIAA 2000-3606

**The NASA ASTP Combined-Cycle Propulsion Database
Project: A Progress Report**

Eric H. Hyde
NASA Marshall Space Flight Center
Huntsville, Alabama

Daric W. Escher, Mary T. Heck,
Jordan E. Roddy
Science Applications International Corp.
Advanced Technology Group
Huntsville, Alabama

ABSTRACT

BACKGROUND / PURPOSE

The National Aeronautics and Space Administration (NASA) communicated its long-term R&D goals for aeronautics and space transportation technologies in its 1997-98 annual progress report (Reference 1). Under "Pillar 3, Goal 9" a 25-year-horizon set of objectives has been stated for the Generation 3 Reusable Launch Vehicle ("Gen 3 RLV") class of space transportation systems. An initiative referred to as "Spaceliner 100" is being conducted to identify technology roadmaps in support of these objectives. Responsibility for running "Spaceliner 100" technology development and demonstration activities have been assigned

to NASA's agency-wide Advanced Space Transportation Program (ASTP) office located at the Marshall Space Flight Center.

A key technology area in which advances will be required in order to meet these objectives is propulsion. In 1996, in order to expand their focus beyond "all-rocket" propulsion systems and technologies (see Appendix A for further discussion), ASTP initiated technology development and demonstration work on combined-cycle airbreathing/rocket propulsion systems (ARTT Contracts NAS8-40890 through 40894). Combined-cycle propulsion (CCP) activities (see Appendix B for definitions) have been pursued in the U.S. for over four decades, resulting in a large documented knowledge base on this subject (see Reference 2).

In the fall of 1999 the Combined-Cycle Propulsion Database (CCPD) project was established with the primary purpose of collecting and consolidating CCP related technical information in support of the ASTP's ongoing technology development and demonstration program. Science Applications International Corporation (SAIC) was selected to perform the initial development of the Database under its existing support contract with MSFC (Contract NAS8-99060) because of the company's unique combination of capabilities in database development, information technology (IT) and CCP knowledge. The CCPD is summarized in the descriptive 2-page flyer appended to this paper as Appendix C. The purpose of this paper is to provide the reader with an understanding of the objectives of the CCPD and relate the progress that has been made toward meeting those objectives.

OBJECTIVES OF THE CCPD

Providing an Easily Accessible, User-Friendly and Powerful Knowledge-Base Tool

Accessibility Issues

The CCPD has been designed from its initiation to be available via the Internet. While this will maximize the availability of this tool, it also requires that appropriate steps be taken to protect sensitive material. The CCPD will contain no data that is currently considered classified. It will contain data that; has been declassified, has International Traffic in Arms Regulation (ITAR) restrictions, is limited to Government & Government Contractors Only, and is Company Private or Proprietary. To assure that access to the data is appropriately controlled, the CCPD administrator shall require that each user submit a request for access. These requests will then be reviewed and categorized as to the level of access allowed, and, if approved, the user will be assigned a password. Each piece of data shall also be reviewed and categorized as to the level of access restriction to be enforced. This categorization shall appear clearly on the coversheet of each document. Any data that has been declassified shall be carefully reviewed to assure that it is appropriately marked throughout. The password requirement and other appropriate computer security techniques shall protect access to the common server on which the CCPD will reside.

Figure 1 shows the Login Screen of the CCPD. This screen further addresses the accessibility issue by citing the ITAR restrictions that applies to some of the data within the CCPD.

This website contains information which falls under the purview of the U.S. Munitions List, as defined in the International Traffic in Arms Regulations. It shall not be transferred to foreign nationals, in the U.S. or abroad, without specific approval. Penalty for violations is described in ITAR, Section 127. Access authorized for U.S. Government Agencies and U.S. Government Agency Contractors ONLY. Other requests for access of this website shall be directed to the Space Transportation Directorate, Marshall Space Flight Center.

COMBINED-CYCLE PROPULSION DATABASE

The Combined-Cycle Propulsion Database (CCPD) will provide vital information on advanced propulsion systems and technologies for use by the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), its contractors, and other appropriate users. A primary goal is to preserve, whenever possible, rare, significant, one-of-a-kind or little known combined-cycle aerospace-related documentation, and to consolidate this material in the proposed CCPD for future use. The primary emphasis is on identifying, screening and retrieving those documents that might otherwise be lost with time.

ENTER DATABASE

Login:

Password:

Database Stats: 102 6 11 4 0












Figure 1. CCPD Login Screen

Advantages of Internet Accessibility

The advantages of allowing the CCPD be accessible via the Internet are numerous. The Internet is accessible to anyone with a computer and a modem or other means of connection. This will allow the CCPD to rapidly provide access to its resources to qualified engineers and scientists at NASA Centers, and within Industry and Academia. Developing the CCPD through a website allows the development team to take advantage of basic Internet technologies such as web servers, web browsers, and TCP/IP networks. This provides a very cost-effective means of implementing and managing data access, while achieving platform independence.

User-Friendly Interface

The Graphical User Interface (GUI) has been developed to be as intuitive as possible. Features such as "point and click", drop down menus and hyperlinking have been used extensively to establish a user-friendly operation and "feel".

Numerous Features of the CCPD; Documents are the First Priority

The CCPD provides the user with a wide variety of prospective operating features. These include; tutorials, a newsletter, a set of CCP related links, a list of key people in the world of CCP, a multimedia gallery and a toolbox. The informational "heart" of the CCP lies in its resource of key documents. The major effort in the initial phase of development has been concentrated on establishing the capability of the CCPD to provide the user with direct access to these documents. An emphasis has been placed on obtaining the best quality "copy" of the document possible. In the vast majority of cases the CCPD provides the user the ability to read, print and search the document's text and examine any figures and photos within. This is a unique feature delivering a powerful and time saving usability.

Preserving the Investment of the Past

The CCPD was established upon the premise that CCP Research & Development (R&D) efforts of the past are highly relevant and of significant value to current activities. This premise is supported by the commonality of the general past and present nature of the research, and by the size of the "sunk investment" (several billions of dollars) that these programs represent. One of the primary objectives of the CCPD is to preserve as much relevant data as possible before the information and the ability to understand it is lost.

The retention of the experience that this documentation represents is dependent on the ability to: 1) identify key projects and associated documents, 2) locate and obtain high quality copies of these documents, 3) interpret and place the data within these documents in today's perspective, and 4) organize, keyword and index these documents in a manner that facilitates the accessibility of the data. It is critical in all of these processes to involve people who have direct and appropriate experience, preferably in the time frame of the generation of the documents. It is becoming more difficult to find such persons. This is one of the reasons that it is critical to develop and expand the CCPD now.

Classes of Documentation

Documentation of these past R&D programs can be divided into three classes: 1) formally documented and widely distributed documents (e.g. contract final reports), 2) less formally documented data items with more limited distribution (e.g., quarterly reports, presentation material, product brochures), and 3) "one of a kind" undistributed material (e.g. research logs, drawings and data sheets). All three classes represent potentially valuable data with differing challenges in the process of acquisition and retention. As discussed above, it is critical to involve cognizant people in this process, especially in obtaining Class 3 material. In the initial phase of the CCPD development, the strategy is to focus on obtaining **original** copies of Class 1 material to produce the highest quality electronic record possible.

Challenges Faced in the Collection of Documents

The general purging of old documents as regularly instigated by government and industry organizations presents an obvious challenge to the ability to collect archival data. CCP material has been particularly vulnerable to these purges due to the fact that; a) much of this material was initially classified and was therefore more expensive to retain, and b) R&D in the area of CCP has been subject to long periods of time without substantial funding and thus, the justification for keep older records became more difficult. Several cases were experienced during the initial development of the CCPD where valuable CCP archival were lost or destroyed. This is an additional reason why it is critical to populate the database now, especially in the case of archival items.

Class 1 documents can often be found through more "traditional" databases such as NASA's Scientific and Technical Information (STI) service organization and the Department of Defense's (DoD's) Defense Technical Information Center (DTIC). The usual problem with material from such sources is the quality of document reproduction. Quite often this material has been reproduced from an already poor "original" or even from microfiche. The text in the documents is

sometimes hardly readable and less likely to be successfully translated electronically into searchable text. The figures and photographs are quite often unreadable. This obviously compromises the utility of the document to CCPD users.

Increasing the Utility of Past CCP Efforts to Current CCP Practitioners

A major objective is to create an easily accessible database which provides users currently supporting CCP efforts (or those just interested in CCP information) a starting place for the understanding and exploration of CCP related information. In order to achieve this objective, it is necessary to go beyond just providing a consolidated source of high quality copies of key documents. Several special features strive to meet this need by providing "value added" information.

Synopsis and Perspective Statements

A common problem facing the user is the fact that many of the key documents are several hundred pages in length but contain no summary or abstract. It is very uncommon for these documents to contain any information regarding the rationale or justification of the pursuit of the contracted effort. Further, they are often written by people who had no need to relate their work to the "big picture". This can prevent the effective use of the document simply because the user does not have the necessary time to review the entire document. The CCPD will address this limitation by providing a short *Synopsis* (less than a page) of the document and a *Perspective* statement. The *Synopsis* will concisely provide the user with an overview of the document calling out the key information it provides. This can be thought of as the equivalent of an *Abstract*.

The *Perspective* statement will address the issue of placing the document into the "big picture". This will include comments on how the effort relates to past and current activities and while providing other "pieces of the puzzle" that allow the user to better understand the information in context. Once again, it is important

that this information be written, or at least reviewed, by someone with the appropriate background and experience.

Keywords and Indexing Structure

The ability to locate relevant information within any database is highly dependent upon the organization of the material with respect to its keywording and indexing structure. The contents of the CCPD are usually quite subject specific, in comparison to other broad technical databases. It is therefore necessary to develop a unique *CCPD Thesaurus* of keywords and indexing structure. This needs to be done in a manner that maximizes the compatibility with existing databases, while providing the user the necessary search resolution to efficiently locate the information needed. This activity most definitely requires the involvement of people with a wide range of CCP subject knowledge, hopefully, those with directly applicable experience.

Top-Level CCPD Information

Another “value added” product is to provide the user with very top level information related to CCP. This responds to the need of the user to quickly gain a general understanding of the overall significance of the CCP information being accessed. An example of this is the development of an interactive “timeline” which illustrates when, over the past 40 years or so, various project activities occurred. The user will have the capability to inquire into the details of that particular decade of activity, or specific project of interest. This inquiry can lead the user directly to the access of specific documents and other resources contained within the CCPD which relate to that project.

Another example of a top-level value feature is the development of a table that presents a summary of achievements of the key CCP projects. This table will be constructed in such a way that the user can more readily establish the current “state of the art” and deduce what has and has not yet been accomplished.

CCPD Tutorials

The database will also contain general tutorial information to assist the user in understanding the basic principles of CCP. Selected documents that are in and of themselves tutorials in nature will be included to partially address this need. Efforts will also be made to develop new tutorial material as another "value added" feature. One example of this is an integrated graphical and text description of the hardware makeup of a specific engine down to the subsystem level. Another example is an interactive animation of the operation of specific CCP engines. These tutorials will take advantage of the impressive audio/video capabilities of today's personal computers (PCs) and the Internet to making for both informative and interesting technical portrayals. Hyperlinks will be employed as appropriate to allow the user to then access the more detailed documentation resources of the CCPD.

CCPD DESCRIPTION & DEVELOPMENT STATUS

Current Status of CCPD

The CCPD has recently entered the "Beta Test" level of development. The overall software has been successfully operated in the intended final environment. Each of the constituent modules has been initially populated and demonstrated. The document population has reached a level of over 100 items with over half of these having been provided with a Synopsis and/or Perspective statement. The internal document search features have been exercised and demonstrated to be performing accurately.

Platform, Database Selection / Modular Architecture

The CCPD is based on a Microsoft Access database served up on an NT Server Platform with the DT search engine, Adobe Acrobat and Flash components. Microsoft Access was chosen because of its ease of use and its scalability to an SQL Server when the need arises. The CCPD System is being developed using a modular approach that allows modules to be deployed, as they become available and to provide a "common look and feel" throughout. This capability

was demonstrated when a new feature, referred to as the Timeline, was successfully introduced midway through the initial development period.

CCPD Module Descriptions

The initial modules deployed include the following: Document Search, Tutorials, the Toolbox, Who's Who, Links, the Gallery , CCP Today and the Timeline

Document Search Module

The ability to quickly find information is the key to any database. Therefore the efficiency and utility of the search techniques provided is very important. The CCPD offers the user three different search methods, each of which has its strengths and weaknesses.

The "Smart" full document text search is a unique and powerful feature of the CCPD. Because the documents held within the database have all gone through an Optical Character Recognition (OCR) process, it is possible to provide the user with a search technique that looks for matches to the user's search criteria **within the text of the documents**. This search returns its results in the form of a listing of documents ranked by the number "hits" (matches) found. When the user determines which document to further examine by simply clicking on the Title, the document is brought up with area at or very near the "hits" highlighted. This is illustrated in Figure 2.

This search method supports a number of search options including single word or phrase with Boolean support and natural language searching. A "fuzzy" search option allows for typographical or spelling errors and the stemming search option can be used to find different word variations. To find words that sound alike, a phonic search option is also available. The strength of this document search method is the resolution of the search. The major weakness is the user's ability to employ the various search options available to properly define the search criteria. Another weakness is the ability to accurately apply OCR to

documents with a wide variety of quality. Impressively, the amount of time required to execute this type of search is on the order of 10 seconds.

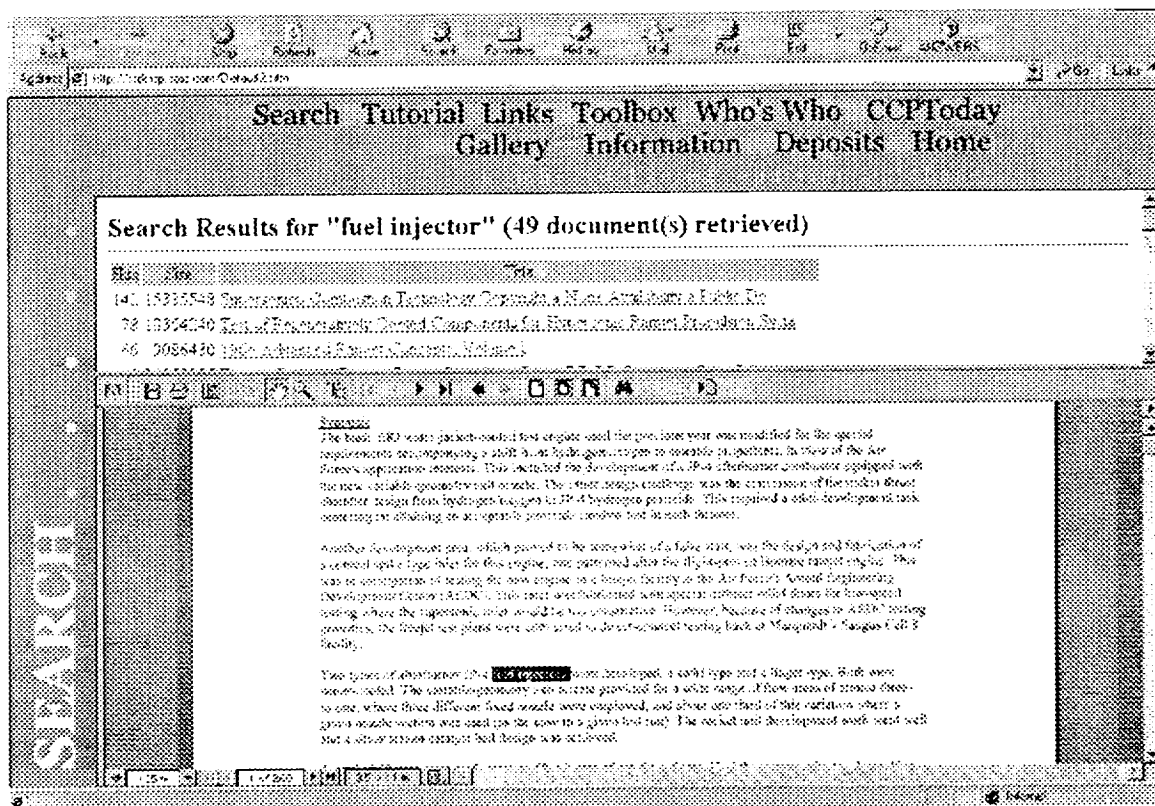


Figure 2. Results from a "Smart" search

A more traditional search technique is referred to as the "general" search. This technique matches the user's selection of database fields such as Title, Author, Date of Publication and Keywords to those associated with data contained within the CCPD. The capability to apply Boolean logic to multiple criteria is also addressed. The strength of this technique is that most users are very familiar with it. The major weakness is that it is only as good as the information that has been input in the datafields.

The final search technique provided by the CCPD is the Browse or drill down method. This method allows the user to find documents by flowing down through a predefined hierarchical structure that is driven by categories and sub-categories. The strength of this technique is the logic of the hierarchical structure

when presented to a user who understands where the information sought fits in. The major weakness is that it can be very difficult to organize data in this type of structure.

Tutorial Module

The Tutorial module provides the opportunity for the user, whether a seasoned engineer or a new graduate, to step through the basic functions and operational

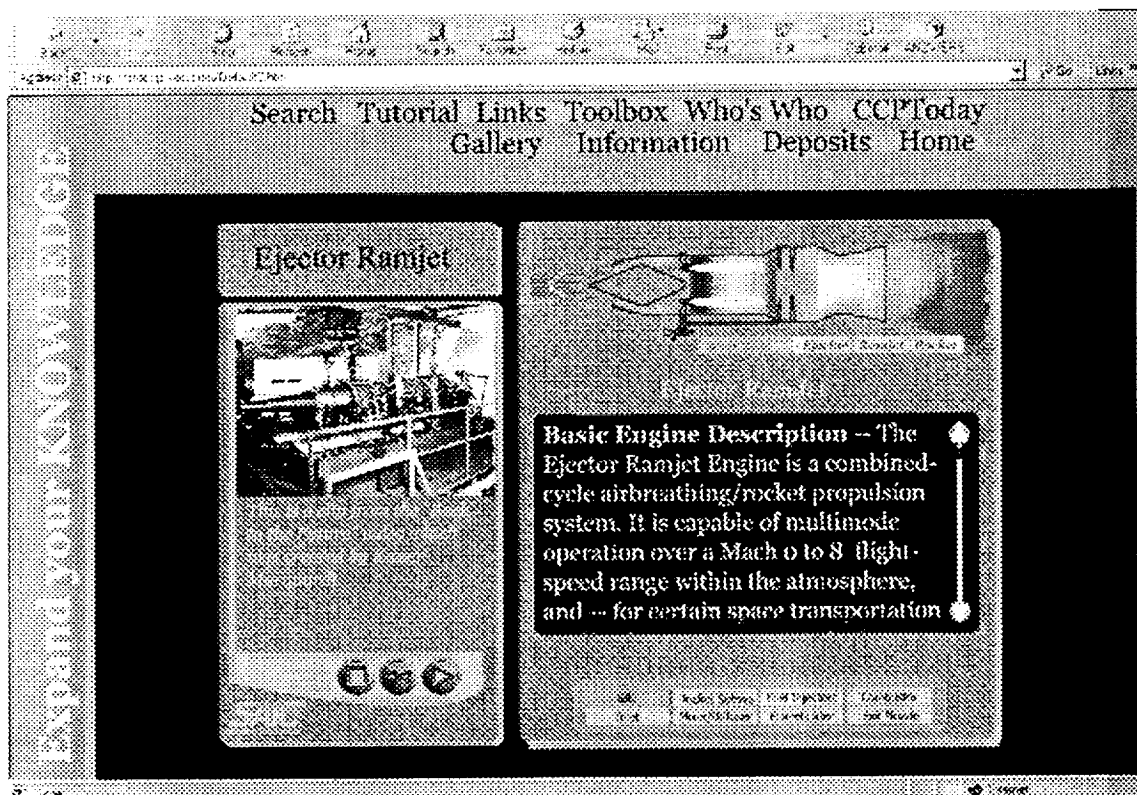


Figure 3. Ejector Ramjet Tutorial

concepts of various engines. Currently, the Ejector Ramjet (shown in Figure 3) and Liquid Air Cycle Engine (LACE) propulsion systems are depicted using line drawings, animation and a variety of multimedia effects, making the presentation both informative and engaging.

Toolbox Module

The Toolbox provides an archival function for computation design analysis and synthesis tools both past and present. applicable to future developments. It also provides the important and searchable description of the tools in some detail and, if available, the ability to download them. Currently, several tools from the Georgia Institute of Technology's Space System Design Laboratory (SSDL) have been included in the Toolbox.

Who's Who Module

Who's Who is the module that captures the biographies and special areas of interest and expertise of individuals that have or are making contributions to the CCP knowledge base. These brief biographies are dynamically linked to the author related documents within the database. Applicable locator information is provided to the user to allow direct connectivity to these leading participants in the field. Currently, some ten individuals have been included.

Links Module

The Links module provides the user with a list of Internet sites which are related to CCP. This links may include; other databases, NASA homepages, Academic institutions, and Industrial homepages . These sites are directly accessible via hyperlinking including a half dozen sites in the current version of the CCPD

Gallery Module

The gallery module is the location for multimedia related to CCP. This can include data such as still pictures, audio soundbytes, animations and movies. The initial population of this module includes samples of each anticipated multimedia type such as multimode operation of rocket based combined cycle engines, historical accounts of previous flight experiments, and supersonic inlet design considerations.

CCP Today Module

The CCP Today module is planned as a newspaper format bulletin board that provides the status of current concepts & technologies, reports on testing successes/failures, and project results. It is intended to be a medium for identifying both shortfalls and advances in technologies and while also providing "community service" items such as meeting notices and topical event announcements. A "mock up" edition of CCP Today is currently being used.

The Timeline

The Timeline does not quite fit into the normal definition of a CCPD module. It is really a top-level tutorial mixed with an alternative data search technique. As previously described, this optional view of the database provides the user with a chronological layout of the key CCP programs and projects. The user then has the capability to first select a decade and then a program or project of primary interest. A textual description of the program or project is then provided along with some still pictures or animations. The user can then request a full listing with direct access to any data within the CCPD which is related to this program or project.

PLANS FOR FUTURE ADDITIONS AND IMPROVEMENTS TO THE CCPD

Additional Documents, Summary and Perspective Statements

The primary area of expansion to the CCPD will be that of the document database. It is anticipated that over 200 additional documents will be processed and incorporated within the CCPD before the completion of the current development phase. The effort to generate Summary and Perspective statements for the critical documents will continue.

Generation of a Summary Level Table of CCP Achievements

As discussed in the Objectives, a comprehensive tabular presentation able to convey to the user the overall sense of what has been accomplished, and what

yet remains to be accomplished in the ongoing field of CCP developments would be very useful. While the generation of such a table is a significant challenge, steps will be taken during the remainder of the current development phase to gather data to initially populate this table. In addition, a set of succinct statements that support this general objective will be developed and incorporated in the CCPD.

Development of CCPD Thesaurus and Indexing Architecture

Currently the CCPD is utilizing an initial list of keywords, which is updated as new documents are added. This list needs to be evaluated and a comprehensive effort initiated to establish a more permanent Thesaurus. In a similar manner, the current document categorization technique requires improvement, including the establishment of a more comprehensive and permanent format.

Search Engine Improvements

Planned future enhancements include enabling the search engine to perform thesaurus searching to find related concepts and synonyms, along with the use of full text searching within the Access database to find key records. The search engine will support the addition of datafields as well as the inclusion of the improved Thesaurus and indexing architecture.

Population of the CCPD Modules

Additions will also be made to all of the CCPD modules. The Who's Who module will be expanded to capture a full representative cross-section of the CCP community. Effort will be made relating to the Toolbox to increase the level of documentation and the number of tools assimilated. There are also plans to incorporate additional tutorials and timeline components. The Gallery and Links modules will expand naturally as additional multimedia and Internet sites are identified.

ACKNOWLEDGMENTS

The preparation of this technical paper providing a progress report on the NASA-ASTP Combined-Cycle Propulsion Database (CCPD) was accomplished by the authors at NASA MSFC and Science Application International Corporation's Advanced Technology. This reporting effort was supported by the National Aeronautics and Space Administration's Advanced Space Transportation Program (ASTP) office at the George C. Marshall Space Flight Center. The contractual support received was through SAIC's Contract NAS8-99060's Technology Assessment Task 4.1.2, "Technology Evaluation and Analysis." The CCPD development effort is being pursued for NASA by SAIC under Task 4.1.2.6 of the contract.

The authors are pleased to acknowledge this NASA and SAIC support, pointing out that the specific commentaries and opinions published here are not necessarily those of NASA or SAIC, but rather are the expressed views of the authors.

REFERENCES

- 1 Anon., "Aeronautics & Space Transportation Technology -- Three Pillars for Success, Turning Goals Into Reality," NASA Annual Progress Report for 1997-98
- 2 Escher, W.J.D., "A U.S. History of Airbreathing/Rocket Combined-Cycle Propulsion for Powering Future Aerospace Transports -- With A Look Ahead to the Year 2020," Paper ISABE-7028 presented at the 14th International Symposium on Air Breathing Engines (ISABE), 5-10 September 1999, Florence, Italy

APPENDIX A

CCPD Brochure

(2 Pages)

APPENDIX A (Cont)

CCPD Brochure

(2 Pages)

APPENDIX B

COMBINED-CYCLE PROPULSION SYSTEMS: KEY DEFINITIONS

Combined airbreathing/rocket propulsion systems are of two basic kinds: 1) *combination* propulsion systems and 2) *combined-cycle* propulsion systems. These two classes, and several subclasses of the combined-cycle type, are defined in Table 1 and further discussed below.

Combination Propulsion Systems -- If the airbreathing and rocket propulsion *engines*, are separately installed on the vehicle and generally do not physically or functionally interact with one another, the overall installation is referred to as a combination propulsion system. Today's solid-rocket boosted turbojet and ramjet-powered cruise missiles are examples of combination propulsion systems. While such systems remain of interest to today's space transportation development community, the principal focus of the subject database is combined-cycle propulsion.

Combined-Cycle Propulsion Systems -- An alternative powerplant type where the airbreathing and rocket elements are closely integrated as constituent *subsystems* into a single engine, is known as a combined-cycle propulsion system. The airbreathing and rocket elements are each tailored such that they optimally interact, both physically and functionally. This propulsion integration approach provides several distinct engine operating modes to match engine thrust demands and flight conditions. This results in a single, lighter weight, more versatile motive power system than that using the combination system separate engine approach and uniquely offers important new propulsion operating capabilities.

APPENDIX C

PROSPECTIVE ROLE OF COMBINED-CYCLE PROPULSION IN THE ADVANCED SPACE TRANSPORTATION SYSTEMS DEVELOPMENT FIELD

Aerospace propulsion systems fall into two major classes: 1) airbreathing propulsion and 2) rocket propulsion. To date, airbreathing propulsion has exclusively served the large, long-existing aviation community. Rocket propulsion, comprising both liquid- and solid-propellant types, has been the propulsive mainstay of all spaceflight endeavors so far.

But today, those involved with advancing the field of space transportation systems are facing unprecedented challenges such as those exemplified by NASA's *Spaceliner 100* technological initiative goals. These challenges ask for no less than today's aircraft-like levels of flight safety and operating dependability, and full "ticket price" affordability. A leading engineering response toward meeting these revolutionary goals is to integrate airbreathing propulsion's high specific impulse performance and operating agility, with the demonstrated strengths of the rocket – which include, high thrust/weights and the ability to operate in a space environment. Studies related to the combined-cycle propulsion class system indicate to many advanced systems planners that this approach is a strong candidate for supporting tomorrow's Spaceliner class transportation systems.